ON THE GEOLOGICAL STRUCTURE OF THE MOUNT WASHINGTON MASS OF THE TACONIC RANGE.

(With Two Plates.)

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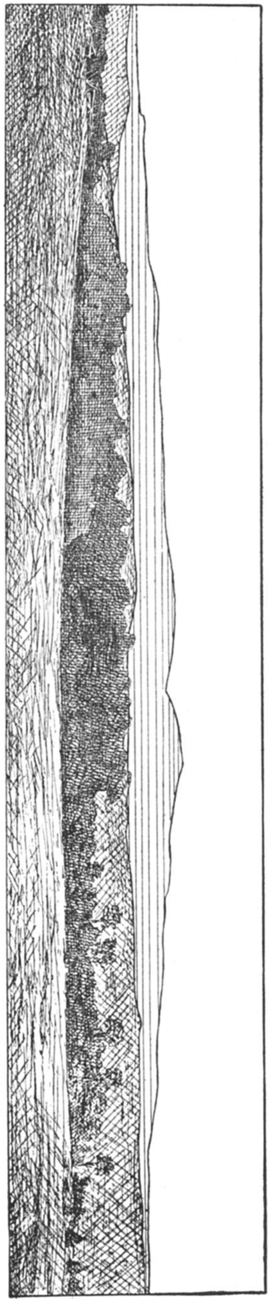
CONTENTS.

THAT portion of the Taconic Range which is known as Mount Washington is both topographically and geologically a unit. It covers an elongated elliptical area, about fifteen miles in length and four and one-half miles in average breadth, lying in the states of Massachusetts, Connecticut and New York. It occupies the entire township of Mt. Washington, and portions of Sheffield and Egremont in Massachusetts; about one-third of Salisbury in Connecticut; and portions of Northeast, Ancram, Copake and Hillsdale in New York.

Topography.—The Mt. Washington mass is a double ridge enclosing a summit plain. Mt. Everett, or the "Dome of the

Taconics" (2624 feet) lying in the eastern ridge, is the highest peak and one of the highest elevations in Massachusetts, while Bear Mountain (2355 feet) is the highest point of land in the state of Connecticut. The main summit plain is situated to the northward of the center of the mass and has an average altitude of about 1700 feet. Corresponding with the elliptical outline of the mountain, this plain is compressed at the north and south, so that its length is about three miles and its breadth two miles. Encircling it is a line of peaks ranging from 1900 to 2600 feet in height. This encircling wall of peaks is buttressed by other peaks both to the northward and southward, the southern side being strengthened by a parallel belt across the mountain, composed of Mts. Bear, Gridley, Frissell and Monument. Southward of this belt of hills the elevated plateau recurs, but without the rampart of peaks which characterize it in the northern and more central area.

The Salisbury-Sheffield valley on the east and the Copake Hillsdale valley on the west of the mass, constitute a floor having an average altitude of 700 feet, from which Mt. Washington rises abruptly, the mean slope-angle being about 20°. The southern boundary of the mountain is the nearly east and west valley



MOUNT WASHINGTON, MASS.
FROM THE EAST
FIG. 1

through which runs the Central New England and Western Railroad. On the northwest Mt. Washington is merged into the narrow ridge of the Taconics, which extends northward into Vermont. The name Mt. Washington, however, applies properly to all of the range lying south of the South Egremont-Hillsdale turnpike. The regular elliptical contour of the mass is broken on the northeast by two deep embayments, the eastern one containing Fenton Brook, and the western, which is knee-shaped, being occupied by Sky Farm Brook. The regularity of contour is further interrupted by an outjutting spur on the west side, known as Cook's Hill. South of the topographical break which limits the mountain in the neighborhood of Ore Hill, the range of the Taconics pursues a more interrupted course, the hills becoming smaller and spreading out considerably.

Previous Work within the Area.—As the aim of this paper is mainly to deal with the problem of mountain structure, no mention will be made of the part which the area has played in the "Taconic Controversy," except as structural facts may be brought out by it. The boundary between the basement limestone and the schistose rock of the mountain was roughly located by Hitchcock[1] for the northern portion, and by Percival[2] for all but the extreme northern portion of the mountain. The former gives (Plate 55 E of the work cited) a section across Mt. Washington, in which the schist and limestone of the east base of Mt. Everett are shown dipping at a steep angle east. Mather[3] gives two sections across the Taconic Range in the vicinity of Mt. Washington. One of these (loc. cit. Pl. XIV, Fig. 1) is from Hillsdale, N. Y. to Egremont, Mass., and passes a little to the north of Mt. Washington; the other (Pl. XVI, Fig. 3) is from Hudson, N. Y., to the southwest corner of Canaan, Ct. The latter crosses the mountain in a northwest-southeast direction and exhibits a synclinal structure.[4]

[1] Geol. of Mass., EDWARD HITCHCOCK, Amherst and Northampton, 1841, Frontispiece Map.

[2] Rept. on the Geol. of the State of Connecticut, J. H. PERCIVAL, New Haven, 1842, Frontispiece Map.

[3] Natural History of New York, pt. iv. Geology, pt. i. 1845.

[4] In his list of dip and strike observations MATHER includes several from the Mt. Washington area (pp. 612–613).

In 1864 James Hall and Sir William Logan[1] visited Mt. Washington and described it as probably synclinal in structure.

The only investigator, however, who has made a detailed study of the geological structure of the mountain is Professor J. D. Dana, whose papers on the subject have appeared mainly in the American Journal of Science. His first paper dealing with the structure of Mt. Washington[2] appeared in October, 1873. It contains a sketch-map with dip and strike observations. On page 38 he states:

"*Mt. Washington is a synclinal with limestone below and slate above.*"

And on page 39:

"We thus find evidence of a very broad synclinal across the center of Mt. Washington. But just north, in Egremont, the structure is totally different; the ridges S and T[3] are the sources of very steep and comparatively narrow independent synclinals with the axial plane inclined westward. * * * The synclinals S and T become merged in one mass in Mt. Washington; and as the limestone does not appear at the smmmit, the intermediate anticlinal in the mountain was only an anticlinal of slate. In other words, the synclinal of limestone beneath the mass of the mountain was one great trough with breaks and incipient flexures; while to the north these incipient flexures became two defined synclinals, with the intermediate anticlinal — the synclinals being courses in the ridges S and T and the anticlinal that of the limestone outcropping between; and then, farther north, there was formed the Taconic synclinal T alone."

In the same year there appeared in the Proceedings of the American Association a paper entitled "The Slates of the Taconic Mountains of the age of the Hudson River or Cincinnati Group.[4] In this paper Professor Dana states that limestone dips west under slates along the east slope of Mt. Washington for four miles, "that is, the whole eastern front." He describes

[1] Paper read by T. STERRY HUNT before the Natural History Society of Montreal, October 24, 1864. Reviewed in the American Journal of Science, 2d ser., Vol. xl, p. 96 (1865).

[2] On the Quartzite, Limestone and Associated Rocks of the vicinity of Great Barrington, Berkshire county, Mass., J. D. DANA, American Journal of Science, 3d ser., vol. vi., p. 37.

[3] The ridge S is that of Mts. Darby, Sterling and Whitbeck, and the ridge T that of Mts. Prospect and Fray near the New York-Massachusetts state line. (Cf. map pl. i).

[4] J. D. Dana, Proc. A. A. A. S., 22d (Portland) meeting, 1873, pp. 27–29.

the mountain as composed of two close-pressed synclinals in the Mt. Washington plateau with steep easterly inclined axes, and that these synclinals are synclinals of slate riding over a single synclinal of limestone.

In 1877, in a paper entitled, "On the Relations of the Geology of Vermont to that of Berkshire,"[1] he adds, referring to the anticlinals of limestone between the three northern spurs of the mountain:

"It has not been possible to follow these subordinate anticlinals southward, because the limestone is not continued far in that direction, and the summit of the mountain is under soil and cultivated farms. But yet the fact of flexure at the north end is strong reason for believing that similar flexures, if not the same continued, characterize the whole length from north to south of the mountain-mass, such a slate easily flexing under uplifting lateral pressure. This is further sustained by observations proving that other subordinate anticlinals exist on the western slope of the mountain, in the vicinity of Copake Furnace. Close to the western foot there are two nearly parallel limestone areas, parallel to the axis of the range. The inner (or more eastern) one is about a mile long, and the other about half a mile. They are separated from one another by a thin belt of hydromica slate, and the same slate exists on the other sides. The dip of the beds of limestone and slate is to the eastward 50°, the strike averaging N. 15° E. (true). They are evidently registers of local folds—anticlinal and synclinal, the former bringing up the limestone."

In the paper "On the Hudson River Age of the Taconic Schists,"[2] Professor Dana has put on record new observations showing the synclinal character of the mountain (l. c., p. 376) and printed a map including a part of Mt. Washington (p. 379)[3].

Another paper, "On the Southward Ending of a Great Synclinal in the Taconic Range,"[4] is specially devoted to a consideration of the structure of Mt. Washington, and contains a map of the southern portion of the mountain on a scale of eight-tenths of an inch to the mile. Professor Dana's earlier conclusions as to the synclinal character of the mountain, had been largely drawn from observations made in Massachusetts. The conclusion that the synclinal character of the northern portion of the mountain is continued to the southern extremity, he drew from the fact

[1] Am. Jour. Sci., 3rd ser., vol. xiv., pp. 262–263.

[2] Am. Jour. Sci., 3d ser., vol. xvii., pp. 375–378 (May, 1879).

([3] Cf. also *ibidem*, Supplement to vol. 18, for dip and strike observations).

[4] *Ibidem*, vol. xxviii., p. 268 (Oct., 1884).

that a number of small limestone areas near Lakeville, in which the strata are but gently inclined, are capped by a schist. This schist he believed to be the same as the schist of the southern extremity of the mountain. He says, speaking of these areas (p. 272):

"Since the limestone is the underlying rock, they are all, if not monoclinal, as is hardly possible, small overturned anticlinals, which have had their tops worn off so as to show the limestone beneath." * * * * * *

"The synclinal structure of the mountain is apparent also along portions of the southern edge of the schist. At Ore Hill, one and a half miles west of Lakeville, the schist overlies limestone."

On page 273 he says:

"The ore-pits that have been opened about the base of Mt. Washington, fourteen in number, are situated near the junction of the limestone and schist, and in view of the facts that have been mentioned, this means—*near where the limestone emerges from beneath the schist.*"

Referring to the dying out of the synclinal to the south of the mountain, he says:

"Again the pitch of the beds in the last three miles is southward in some parts, instead of eastward or westward, showing a flattening out of portions of the synclinal and subordinate anticlinals."

"It thus appears that in the dying out of the synclinal, besides a flattening of portions of the general synclinal and the introduction of southward dips, there was also a multiplication of small subordinate flexures."

"Farther there is a multiplication of ridges of schist in the limestone area."

"Several such ridges, some quite small, are situated, as the map shows, southeastward of the mountain near the village of Salisbury; and others occur farther east. They consist of the same mica schist as the mountain,—they have generally an easterly dip, often a high dip; and the facts seem to show that most of them are *synclinal* flexures; that they occupy the troughs of local synclinals in the limestone; * * * Most of them were, apparently, half-overturned troughs so pushed over westward that the dip of the schist is generally eastward." * * * * * * *

The following is quoted from a paper[1] entitled "Berkshire Geology" (pp. 15–16):

"The Mt. Washington schists lie in a trough very much like that of Greylock, but one relatively shorter in its narrowed part and reversed in position. In the northern half the trough is a very broad shallow one, while to the south the east side is pushed up westward."

[1] Berkshire Geology, by Prof. JAMES D. DANA. A paper read before the Berkshire Historical and Scientific Society of Pittsfield, Mass., February 5, 1885. Pittsfield, 1886.

In Professsor Dana's last series of papers[1] on the Taconic Area, he adds some strike and dip observations and prints a more complete map of the area. In the second of the papers,[2] on pages 439–442, he describes the variations in character of the schist of Mt. Washington as showing a more intense degree of metamorphism in the eastern portions, and in conclusion states (p. 441): "The facts here reviewed relate, it should be remembered, to a single stratum, that overlying the limestone."

The several extracts above given will, I think, sufficiently explain Professor Dana's views regarding the structure of Mt. Washington.

On the geological map of the Taconic area compiled by Mr. C. D. Walcott,[3] the Mt. Washington mass is indicated having the same relations to the rocks of the adjoining areas as is shown on Prof. Dana's map.

Conditions and Progress of the Present Investigation.—The writer made a partial reconnaissance of Mt. Washington in the season of 1889, but the mapping was largely done during the months of July and August, 1891. He was assisted during the season of 1891 by Mr. Louis Kahlenberg, at present instructor in chemistry in the University of Wisconsin. Mr. Kahlenberg has traced the contact of schist and limestone along the west base of the mountain. The work has been in charge of Professor Raphael Pumpelly, then chief of the Archean Division of the U. S. Geological Survey.

The reconnaissance of 1889 was made on the southeastern flank of the mass and furnished only equivocal evidence concerning the relations of the "Stockbridge" limestone of the valley to the schist of the adjacent flank of the mountain. One of the first results of the work of 1891 was the discovery of a calca-

[1] On Taconic Rocks and Stratigraphy, with a Geological map of the Taconic Region, J. D. DANA, Am. Jour. Sci., 1885 and 1887.

[2] *Ibidem*, 3d ser., vol. xxix., June, 1885.

[3] The Taconic System of Emmons, and the Use of the Name Taconic in Geological Nomenclature, by CHAS. D. WALCOTT, Am. Jour. Sci., vol. xxxv., pl. iii. (May, 1888).

reous horizon occupying the central Mt. Washington plateau, and the locating of its boundaries (cf. map). Observations were then made a little to the north of Salisbury village which showed conclusively that the schist of that vicinity is *below* the limestone, the structure of the mountain at that latitude being essentially an anticlinal. On examining next the northern extremity of the mountain, observations were quite as conclusive in proving that the schist of Jug End is *above* the valley limestone, and that the section across the range at this latitude is essentially what Professor Dana has described. This knowledge that we have to do with two horizons of schist, the one lower and the other higher than the limestone of the Egremont valley, was soon followed by the discovery of lithological differences between the different beds, which have furnished the key to the structure. Topographical features soon suggested a course across the mountain through which the limestone might pass and separate the upper schist of the northern portion from the lower schist of the southern portion. Through this path the calcareous horizon of the Egremont valley, considerably modified it is true, has been carefully traced. A large number of observations have been gathered from all parts of the mountain mass. Each of the numerous peaks has been ascended and as many data as practicable have been collected. At this time the southern portion of the mountain had not been carefully studied. Later in studying the area lying to the east and southeast of the mass of Mt. Washington, it was found that the limestone of that section is divisible into two beds separated by a schist, which is lithologically identical with the lower of the two horizons of schist in Mt. Washington. The evidence supporting this and the manner in which the areal relations are illusive in the indications which they afford regarding stratigraphy, will be set forth in a later paper. The lower of the two limestone horizons was found to extend westward and disappear under the schist of the south end of Mt. Washington. The schist overlying it, which so resembled the lower of the Mt. Washington schists, was also traced along the northern border of the limestone into the southern portion of Mt. Washington. The areal

relations in the vicinity of the mountain are set forth on Plate III.

Horizons Represented.—The Mt. Washington series thus consists, not of two members as supposed by Dana, but of four, two of which are calcareous. The calcareous beds alternate with the schists, which have been shown to possess marked lithological differences. The sequence of these beds is as follows: (a) a calcareous horizon which I designate the Canaan Dolomite from its typical development at Canaan; (b) the lower schist bed, which I call the *Riga Schist* from Mt. Riga peak where it is perhaps most typically developed; (c) a calcareous horizon, which I designate the Egremont Limestone from its wide extent in the Egremont valley (this limestone is much modified in all localities above the valley floor); and (d) the upper schist horizon, to which I give the name *Everett Schist* since it assumes its maximum thickness within the area at Mt. Everett. It will be noticed that this sequence corresponds with that which Dale has determined for the Greylock mass in northern Berkshire county.[1] Below are given in parallel columns for comparison the series of Mt. Washington and Greylock:

Mt. Washington Series.	*Greylock Series* (*Dale*).
1. Canaan Dolomite.	1. Stockbridge Limestone.
2. Riga Schist.	2. Berkshire Schist.
3. Egremont Limestone.	3. Bellows Pipe Limestone.
4. Everett Schist.	4. Greylock Schist.

These beds are probably Ordovician though the lower portion of the Canaan Dolomite may, like the Stockbridge Limestone, be Cambrian.[2] No fossils have as yet been found in the vicinity and it is hoped that further search may reveal them. Walcott[3] has

[1] The Greylock Synclinorium, by T. NELSON DALE. Amer. Geologist, July, 1891, pp. 1–7. Also given in detail in a forthcoming monograph of the U. S. Geological Survey, by Professor RAPHAEL PUMPELLY.

[2] On the Lower Cambrian Age of the Stockbridge Limestone, by J. ELIOT WOLFF, Bull. Geol. Soc. Am., vol. ii. 1891. See also DALE, *ibid.*, vol. iii, pp. 514–519.

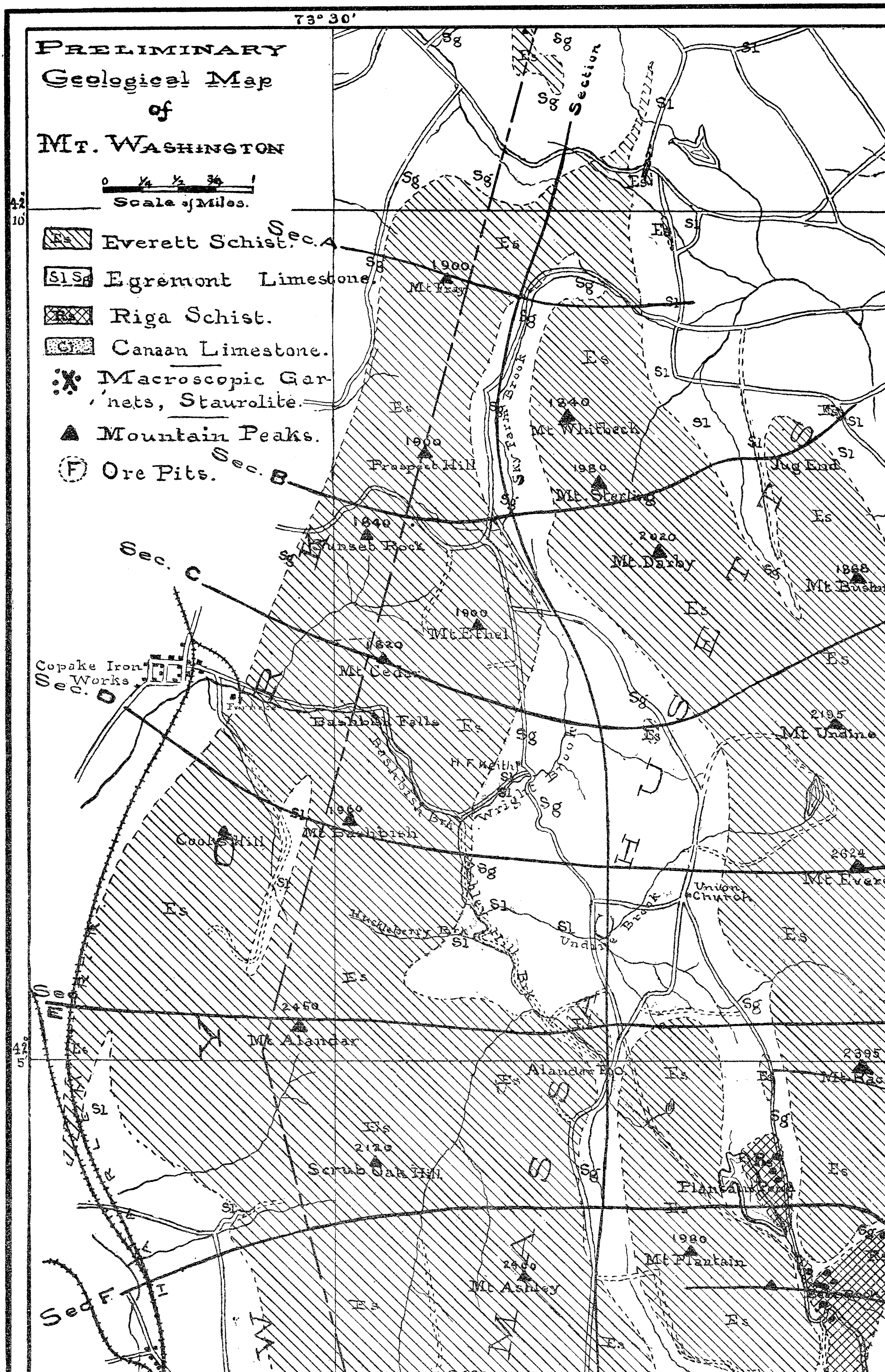
[3] The Taconic System of Emmons, and the use of the Name Taconic in Geological Nomenclature, by CHAS. D. WALCOTT, Am. Jour. Sci., vol. xxxv, pp. 237–242, 399–401, March and May, 1888. (With map).

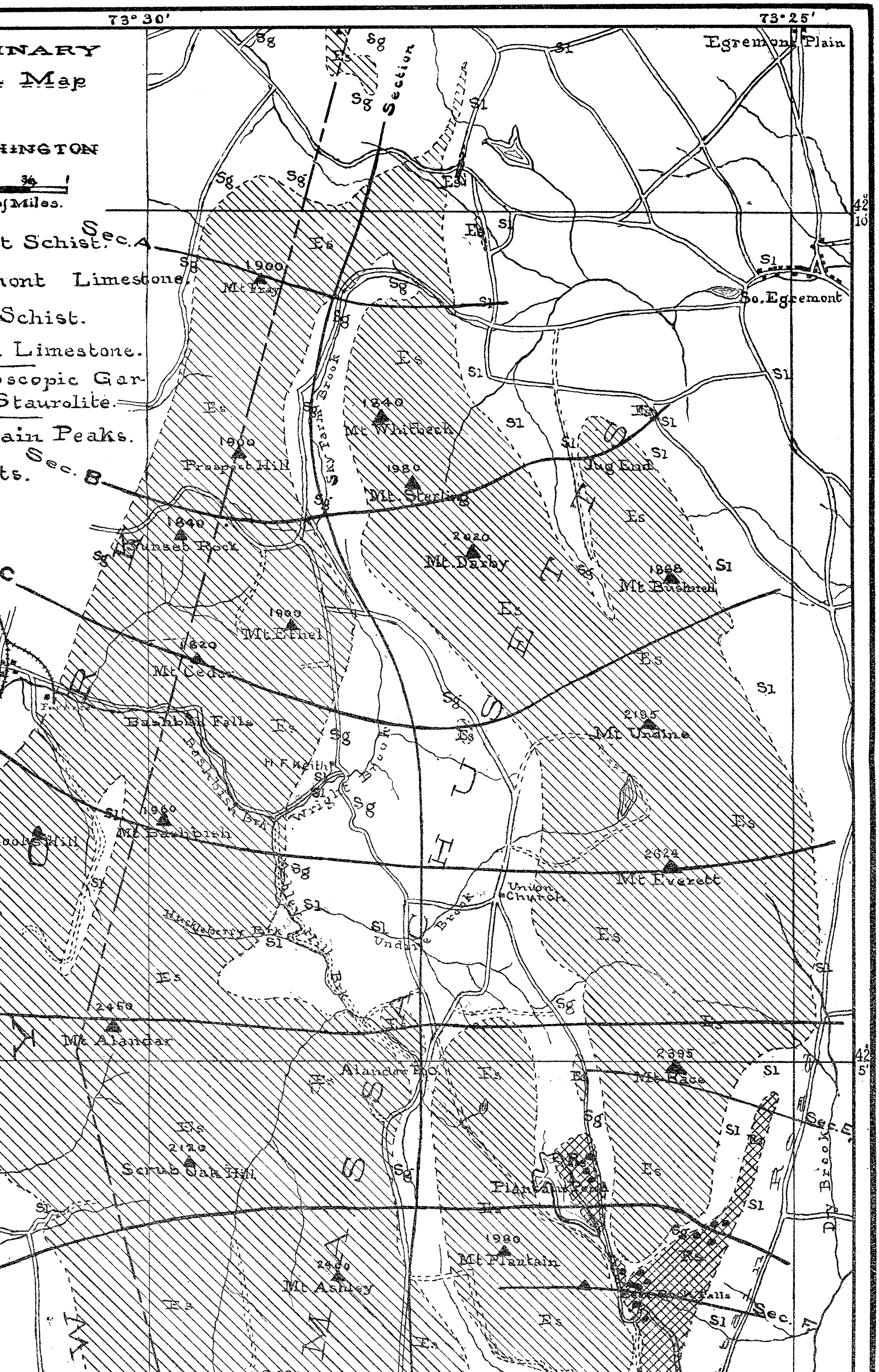
found Ordovician fossils in the limestone belts some distance to the north and Cambrian fossils at Stissing Mountain to the southwest.

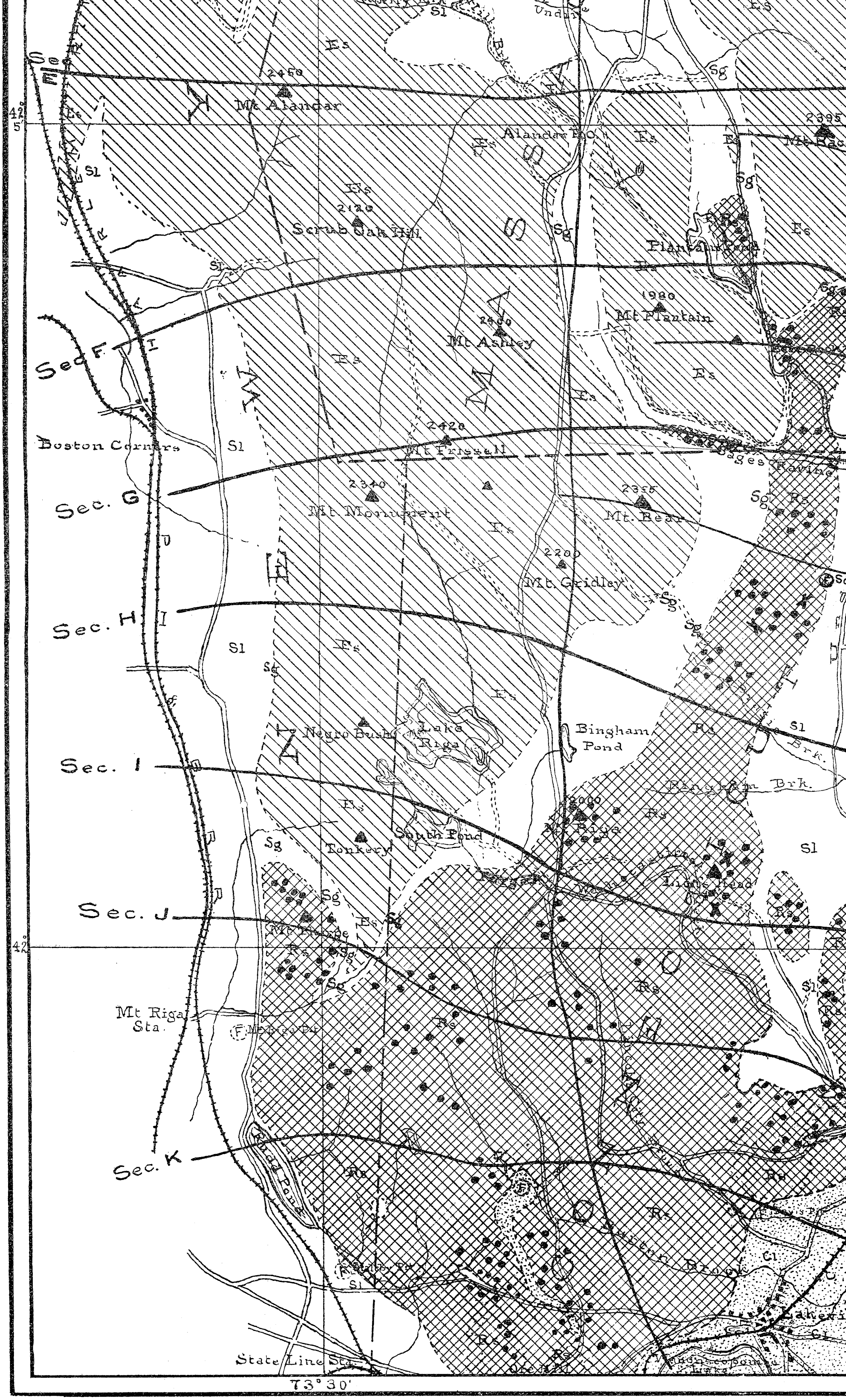
Lithological Character of Horizons.—(a) *Canaan Dolomite*. This bed seems to be very rich in magnesia, the rock being in some cases at least a true dolomite. This is shown by a number of analyses of it by Mr. J. S. Adam.[1] This rock appears at the surface only in the extreme southeastern portion of the area here considered, where it presents few features different from those which are common to the Egremont Limestone. Farther to the eastward, however, and particularly in the vicinity of Canaan, it is often characterized by the presence of interesting metamorphic minerals, the well known salite and tremolite of that locality. Phlogopite also has in one or two instances been found. In its upper layers, where it approaches the overlying Riga Schist, the rock may become graphitic, as at Ore Hill. As it appears in the vicinity of the mountain, however, the rock presents no characters which can be relied upon to distinguish it from the higher Egremont Limestone, and the differentiation is based on stratigraphy alone.

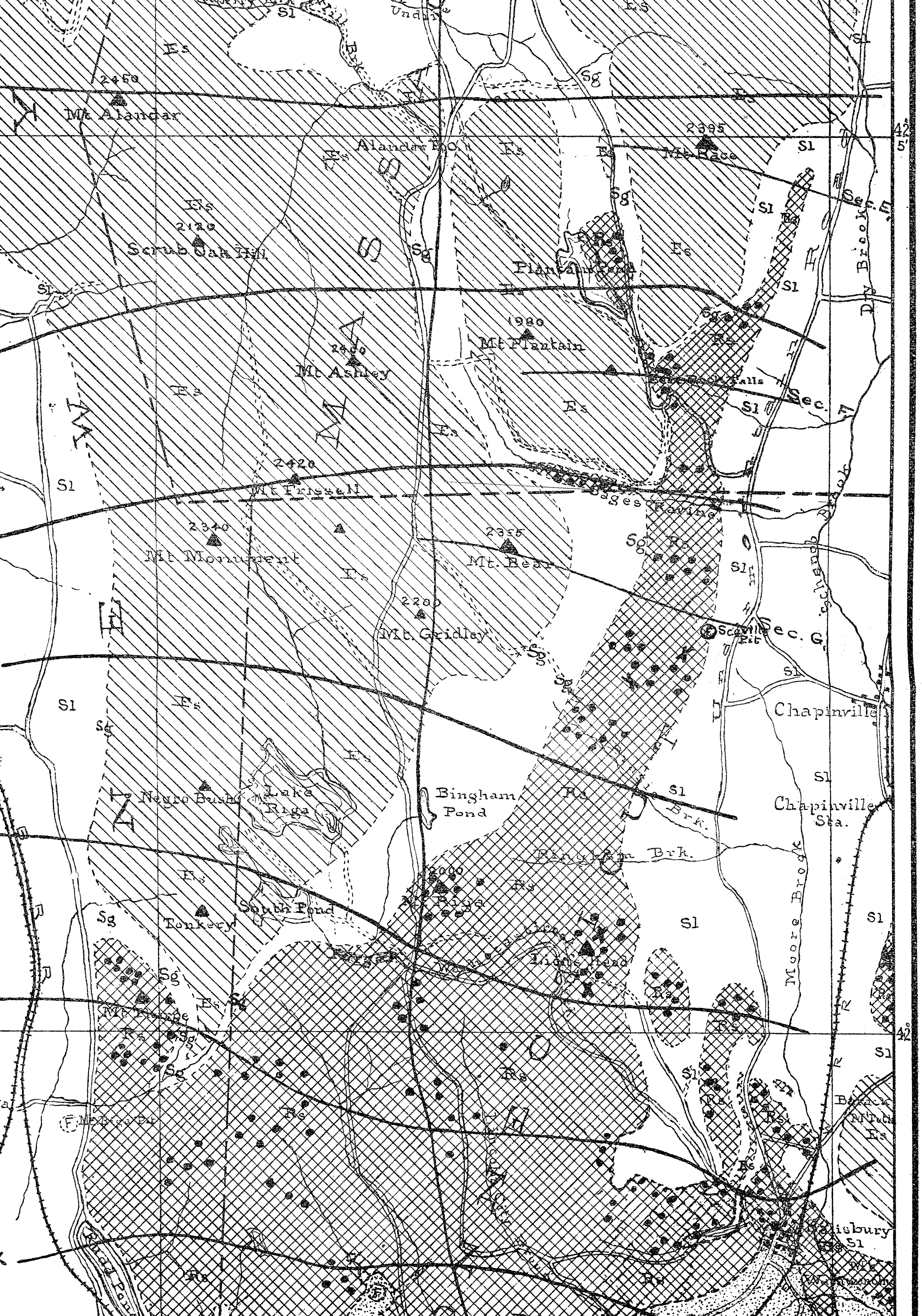
(*b*) *Riga Schist.*—This horizon is tolerably uniform in character, the principal differences being in the presence and variable size of the metamorphic mineral individuals. Strictly speaking the rock is a gneiss, owing to the abundance of feldspar, but in order to distinguish it from more feldspathic and more or less granitoid gneisses lying east of the Housatonic River, it is best to refer to it as a schist, which it most resembles in structure. It almost invariably is porphyritic from the presence of lenticular to spherical grains of an acid plagioclase. The base is usually composed of feldspar, quartz, and a colorless mica (in part sericite) and biotite. Considerable graphite often exists in this base as does also ilmenite. Chlorite when present is usually in small amount. Garnets, staurolite, ottrelite, and biotite, as well as plagioclase, are developed at many localities. On the summit of the Lion's Head the rock contains garnets (rhombic dodeca-

[1] See Am. Jour. Sci., vol. xlv. p. 404, foot note.


Preliminary
Geological Map
of
Mt. Washington
0 1/4 1/2 3/4 1
Scale of Miles.
Es Everett Schist.
Sl Sg Egremont Limestone.
Rs Riga Schist.
Cl Canaan Limestone.
Macroscopic Garnets, Staurolite.
Mountain Peaks.
F Ore Pits.
73° 30'
42 10
42 5
Section
Sec. A
Sec. B
Sec. C
Sec. D
Sec. E
Sec. F
1900 Mt Fray
1840 Mt Whitbeck
1900 Prospect Hill
1980 Mt. Sterling
Jug End
1840 Sunset Rock
2020 Mt. Darby
1868 Mt Bush
1900 Mt Ethel
1820 Mt Cedar
Copake Iron Works
Bashbish Falls
2195 Mt Undine
H F Keith
1960 Mt Bashbish
Cooks Hill
2624 Mt Ever
Union Church
Huckleberry Brk
Undine Brook
Sky Farm Brook
2450 Mt Alandar
Alandar P.O.
2395
2120 Scrub Oak Hill
Plantain Pond
1980 Mt Plantain
2460 Mt Ashley


73° 30'
73° 25'
Map
Miles.
Schist.
Limestone.
Schist.
Limestone.
Staurolite.
Sec. A
Sec. B
Section
Egremont Plain
So. Egremont
1900
1840
Mt Whitbeck
Prospect Hill
1980
Mt Sterling
Jug End
Sunset Rock
2020
Mt Darby
1868
Mt Bushnell
Mt Ethel
Bashbish Falls
2195
Mt Undine
H F Keith
2624
Mt Everett
Union Church
2450
Mt Alandar
Alandar P.O.
2395
Mt Race
2120
Scrub Oak Hill
Plantain Pond
1980
Mt Plantain
Mt Ashley
Dry Brook


Sec. E
2450
Mt Alandar
42° 5'
Alandar P.O.
2395
2120
Scrub Oak Hill
Plantain Pond
1980
Mt Plantain
2400
Mt Ashley
Sec. F.
2420
Mt Frissell
Boston Corners
Sages Ravine
Sec. G
2340
Mt Monument
2355
Mt Bear
2280
Mt Gridley
Sec. H
Negro Bush
Lake Riga
Bingham Pond
Bingham Brk.
Sec. I
2000
Mt Riga
South Pond
Tonkery
Sec. J
Mt Riga Sta.
42°
Sec. K
Ore Hill
State Line Sta.
73° 30'



2450
Mt Alandar
Alandar P.O.
2395
Mt Race
42°
5'
Sec. F
Dry Brook
2120
Scrub Oak Hill
Plantain Pond
1980
Mt Plantain
2400
Mt Ashley
Sec.
2420
Mt Frissell
Sages Ravine
2340
Mt Monument
2355
Mt. Bear
2200
Mt Gridley
Scoville
Sec. G
Chapinville
Chapinville Sta.
Schenob Brook
Negro Bush
Lake Riga
Bingham Pond
Bingham Brk.
Moore Brook
2000
Mt Riga
South Pond
Tonkery
Salisbury
Lakeville
State Line Sta.
42°
73°30'
73°25'
Es
Sl
Sg
Rs
Cl

hedra) over a centimetre in diameter, and staurolites (usually inclined-cross twins) a centimetre or more in length. Tourmaline occurs only in minute crystals, much less widely distributed than any of the other metamorphic minerals except ottrelite. Some of the localities where macroscopic garnets and staurolites were found in the rock have been indicated on the map—small black circles and crosses standing for the two minerals respectively.

(*c*) *Egremont Limestone.*—This horizon as developed in the valley near the base of the mountain, is a white to gray crystalline limestone, which is often quite pure but for small scales of colorless mica and grains of pyrite. Locally it contains thin quartzitic or schistose layers. Generally it passes upward into the Everett Schist of the flanks of the mountain through a graphitic layer of variable thickness, and a similar graphitic rock is also to be found at its lower contact with the Riga Schist. As met with in the summit plains, the limestone appears under two modifications which grade insensibly into one another. They are (1) a very micaceous limestone or calcareous mica schist; and (2) a graphite schist, often, though not always, calcareous. The first mentioned modification is to be found only in the central portions of the northern summit plain, where the larger streams have cut through the thick drift deposits. It is richest in calcite at two localities, one of which is in the bed of Wright Brook about midway between its confluence with Ashley Hill Brook and the north and south road to the east, and the other is in the bed of City Brook. This rock also occurs in the small brook near the house of H. F. Keith, in the bed of Huckleberry Brook, and at several localities on the Ashley Hill road between Huckleberry and Wright Brooks. It always contains a silvery mica, graphite and pyrite.

In the northern summit plain graphitic schist (here generally calcareous) forms a border separating the micaceous limestone from the Everett Schist which surrounds it. According as it occurs nearer the limestone, it is the more calcareous. In the lower course of Wright Brook it contains layers of calcite over a

centimetre in thickness, while on the road encircling the west flank of Mt. Everett it hardly effervesces at all with acid. At localities south of the central plain the rock only rarely exhibits effervescence with acid. The graphite schist differs from the limestone not only in the large proportion of graphite and the correspondingly small amount of calcite which compose it, but its least calcareous varieties contain also much feldspar and quartz. Garnets and tourmaline have each been found in one specimen, the first near the lower, and the second near the upper schist contact.

(*d*) *Everett Schist.*—The rock of this horizon is not in all cases to be easily distinguished from the Riga Schist. Like that rock it is porphyritic from lenticular feldspar grains, but these feldspars are much more abundant and more constant, and the base is generally more chloritic or sericitic. Ottrelite is found sparingly at some localities. The most striking lithological difference from the Riga Schist, however, exists in the *entire absence of macroscopic garnets and staurolites from this horizon*, not an individual of either species having been found within the entire length and breadth of the area of this horizon exposed, though they have been carefully sought at each locality. The beds seem to become more sericitic along the northwestern foot of the mountain. A phase of the rock which is more characteristic of the southeastern portions of the area is very chloritic with magnetite octahedra sometimes as large a pea. Chloritic phases of the rock also appear in the extreme northern areas.

Explanation of Map, Areal Geology.[1]—The eastern and southern portions of the map are based on the Sheffield and Cornwall sheets of the topographical map of Massachusetts and Connecticut by the U. S Geological Survey, and the portion of the map lying in New York State is compiled from older road maps. The manner in which the Egremont Limestone crosses the mountain separating the Everett and Riga Schist horizons, may well be emphasized by special description. On the eastern side the course of the calcareous horizon as it gains the summit plain is

[1] See Plate III.

suggested by topography. The series of sections in Figure 2 will show this in some measure.

Beginning with Mt. Everett, we find that it presents a uniformly steep eastern slope of Everett Schist, the limestone being in contact near the Undermountain Road. Where the slope of Mt. Race begins a little farther south, an abrupt recession occurs in the face of the range, which extends west to the foot of steep cliffs and south to the road north of Sage's Ravine. Into and

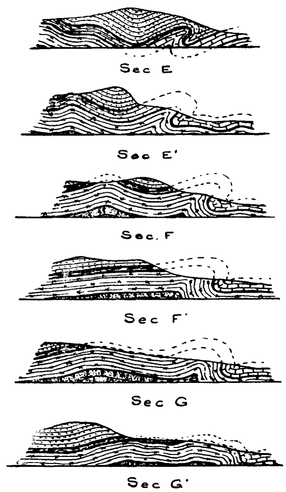


FIG. 2. Series of sections from the east flank of Mt. Washington, showing how the limestone of the valley gains the summit plain.

along this "bench" runs the Egremont Limestone. Proceeding southward from the north end of this "bench," a tongue of schist is met lying within the limestone, about midway between the cliffs and the road, and forming a backbone, the slope immediately west being very gradual while that to the east is tolerably steep. This tongue of schist broadens to the southward, narrowing that belt of limestone which lies to the west of it. As this limestone belt becomes narrowed toward the south, it ascends the mountain, losing as it does so most of its calcite and developing into a black graphitic schist. This reaches the altitude of the summit plain about one-eighth of a mile north of Bear Rock

Falls. From there it is traced with some difficulty along the road to Sage's Ravine, between garnetiferous schists on the east and Everett Schists on the west. The garnets of the eastern schist belt were found to extend northward into the contracted part of the tongue of schist. Immediately north of Sage's Ravine the graphitic rock is distinctly calcareous. West of this point the garnetiferous rock occupies the bed of Sage's Ravine as shown on the map and in sections, while the Everett Schists occur on the road above. To the south of Sage's Ravine and at the altitude of the summit plain, opens a wide bench fully a quarter of a mile in width with the Everett Schists rising abruptly from its western edge in Mt. Bear. To the east of it are thin caps of Everett Schist, then small outcrops of graphitic schists, alternating for a short distance with garnetiferous and staurolitic schists, and finally the latter occurs alone, clearly showing that in the bench and for some distance east of it, the thin bed of graphitic schist lies at the surface. These relations are exhibited in section G′ of Fig. 2. Still farther south this bench is extended into a broad swampy tract on the two sides of which the two schist horizons are shown in outcrops, the garnetiferous rock being on the east and the other schist on the west. This swampy plain outlining the area occupied by the graphitic belt, crosses the north and south Mt. Riga road just north of Mt. Riga (Bald Peak), its northern and southern limits being marked by sharp turns in the road and abrupt rises in the land, as well as by outcrops of the two schist horizons. In the almost continuous areas of exposures in the vicinity of the Mt. Riga Lakes, its course is carved out sharply though the rock is not found in outcrop. Beyond South Pond the belt narrows and begins to be followed with difficulty. The graphitic rock has been found in outcrop in the bed of a stream flowing toward Mt. Riga Station. Farther down this stream is joined by another from the east flank of Mt. Thorpe, containing likewise a belt of graphitic schists (here calcareous) in contact with garnetiferous rock on the west. This belt of graphitic rock is soon cut off to the south, but it is found to join the main valley through a depression of the ridge to the north-

east of Mt. Thorpe, whence it continues northward as a transitional zone between the valley limestone and the Everett Schist. The rock of Mt. Thorpe is filled with garnets, and the area of schist east of the easterly branch of the stream has also abundant garnets, though they have only been found at some distance from the graphitic rock. Between the two forks of this stream, the upper schist rests as in a saddle, its southern termination being a small triangular hill. The southeastern portion of the map, which exhibits areal and structural features of much interest, will receive fuller treatment in another paper, which will deal with the structure of the area to the southeast of Mt. Washington.

Method of Constructing Sections.—The lines of sections have been made as nearly as possible perpendicular to the strike of the strata. The strike has been obtained either by actual measurement with the compass at the locality, or from the directions of the boundaries of horizons. The curvings of the section lines must therefore indicate, either that the crest or trough lines are inclined (pitch) or that the flexures are of variable width. To the southward of section E the average pitch is found to be northward, as shown by the areal relations, and as indicated in the steep southern and gradual northern slopes of the "Lion's Head."[1] To the north of section E the convexity of the section lines towards the south is explained both by southerly pitch and by a greater compression of the flexures in the northern portion. Southerly pitch is suggested by the topography of Mts. Everett and Undine, as well as by the pitching trough and crest lines of coarse corrugations on the slope that rises at the south end of Guilder Hollow (cf. reference to Dale below). These facts when taken in connection with the sections (Plate IV), show the mountain to have a general basin structure.

The determination of the dip is made with great difficulty within the area studied, since the lamination indicative of the plane of bedding is often obscured or even obliterated by subse-

[1] For the detection of pitch by the contour of an elevation I am indebted to Professor Pumpelly for suggestions. He was, I think, the first to discover that these contours betray in an important manner the inclination of the trough and crest lines of folds.

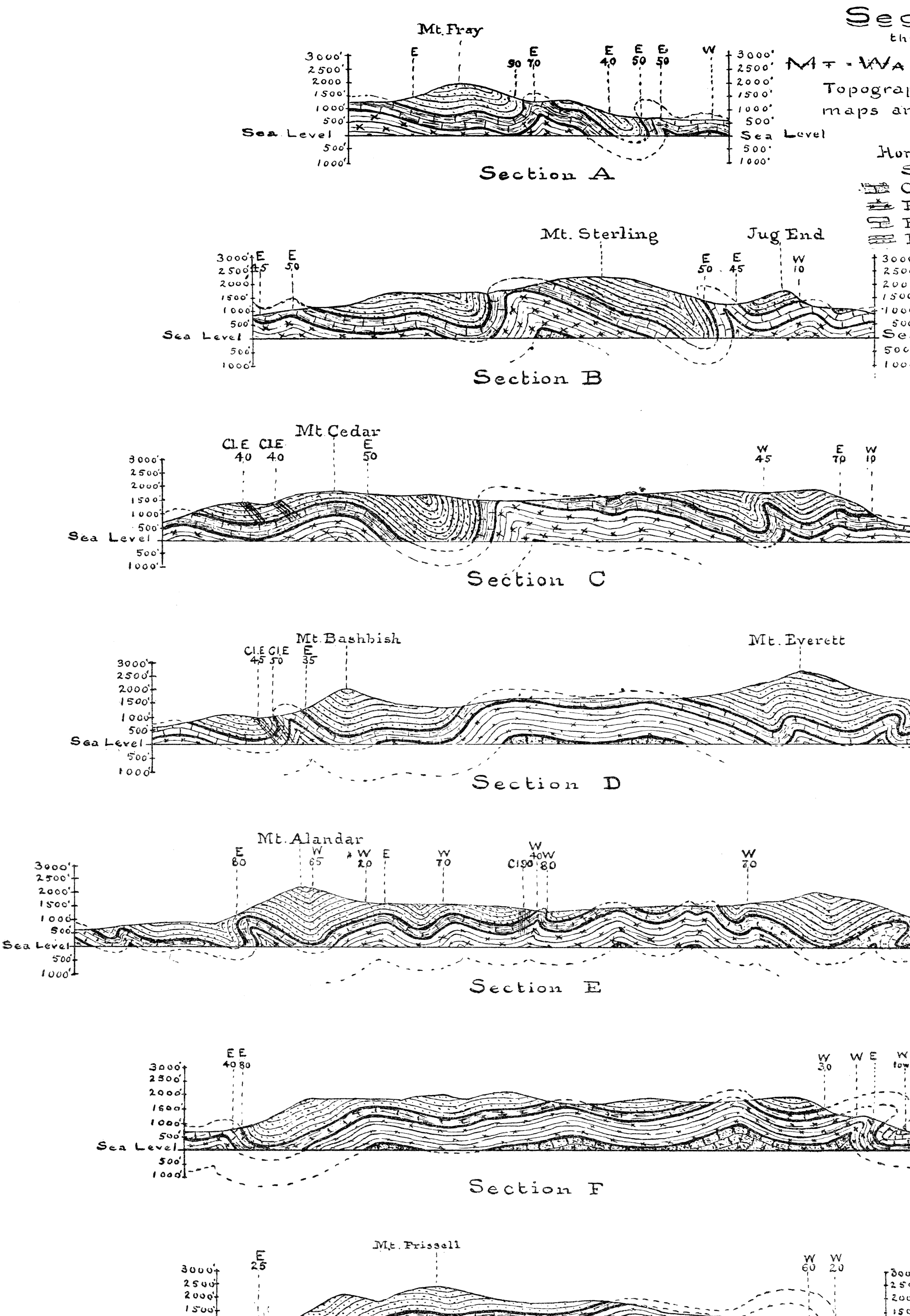
quently induced cleavage structure. In this particular the problems have been essentially those which were encountered in the Greylock area, and similar criteria have been made use of to distinguish the planes of stratification.[1] Hence with the exception of those localities where contacts of the different rocks are exposed, dip observations have been possible at only a few localities where definite plications could be made out.

In the absence of dip observations, the sequence being known, many structural facts have been deduced from the areal relations of the several horizons. Next in importance as a method of determining structure is the interpretation of topographical features. It is by application of all of these methods, whose relative importance is expressed by the order in which they have been mentioned, that the sections have been constructed.

The longitudinal section (Fig. 3) which passes through the mountain in a general north and south direction, nearly at right angles to the cross sections just described, is constructed to show how the northerly pitch of the southern portion of the mountain carries the Canaan Dolomite and the Riga Schist so low that they do not appear again to the northward, for although the pitch in the northern part of the area is southerly, it is not sufficient to entirely counteract the very considerable northerly pitch of the southern portions of the mass.

Structure of the Mountain.—The sections show that the southern portion of the mountain is a geo-anticlinal in the Riga Schist, probably with moderate minor folds tolerably symmetrical. Within the core of this anticlinal is the Canaan Dolomite, which appears from under the schist to the southeast of the

[1] An extensive study of the subject of secondary cleavage as it is met with in the Greylock area, has been made by Mr. T. Nelson Dale, and will appear in full in a monograph by Professor Pumpelly on the Geology of the Green Mountains. A summary of his observations and conclusions is contained in the American Geologist for July, 1891. Mr. Dale has also published a paper entitled, "On Plicated Cleavage-Foliation," in the American Journal of Science for April, 1892. As the writer assisted Mr. Dale during a portion of the field investigation, he became familiar with the structures there exhibited, as he did later also in independent work in the northern stretch of the Taconic Range west of Williamstown.


Mt. Fray
Sea Level
Section A
Topograp
maps ar
Mt. Sterling
Jug End
Sea Level
Section B
Mt Cedar
Sea Level
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Section D
Mt. Alandar
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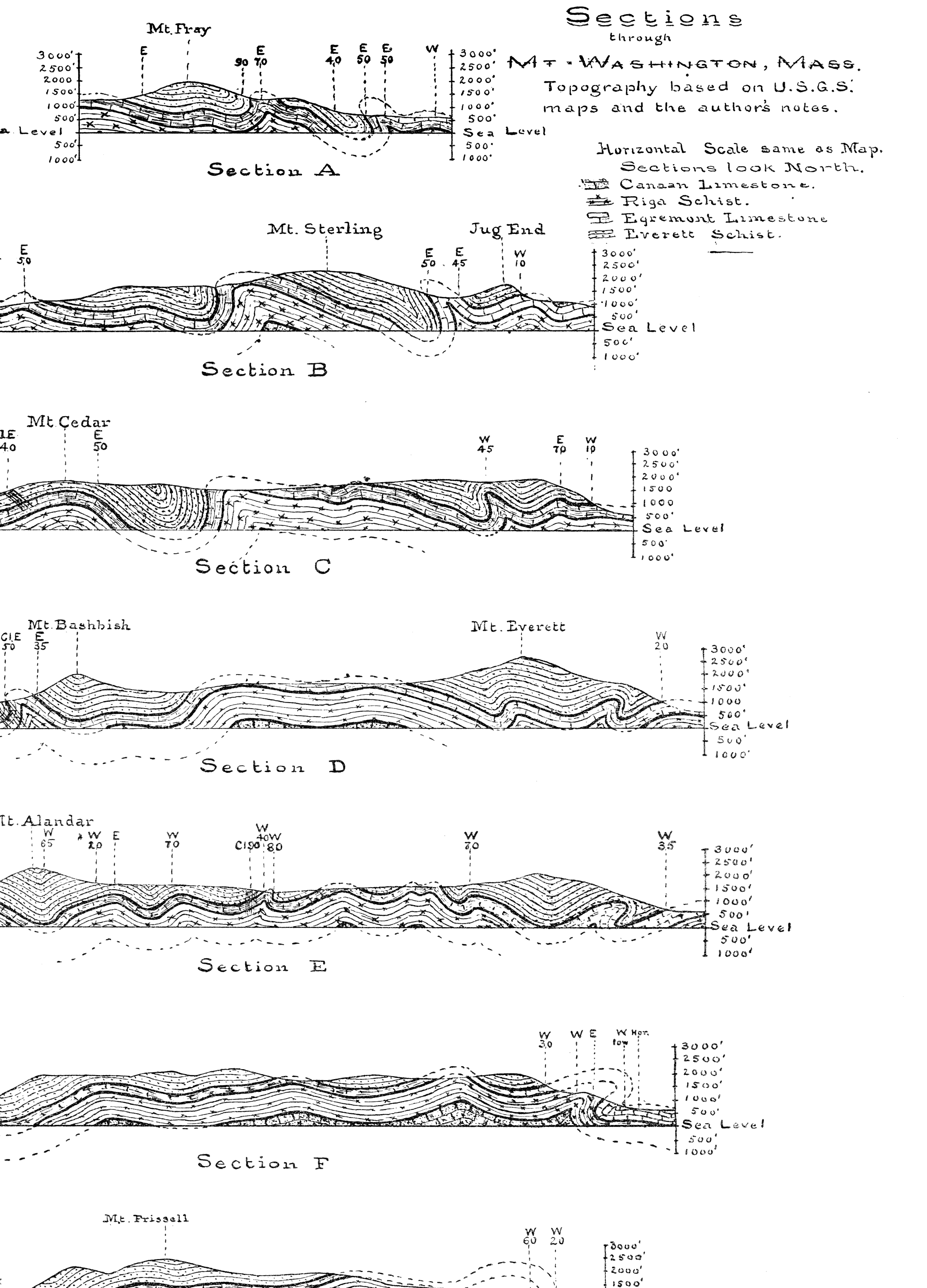
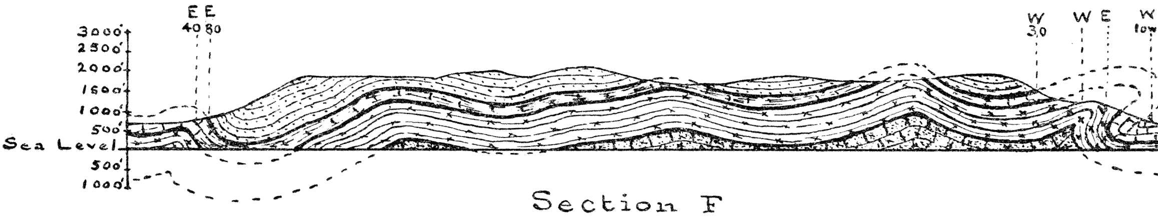
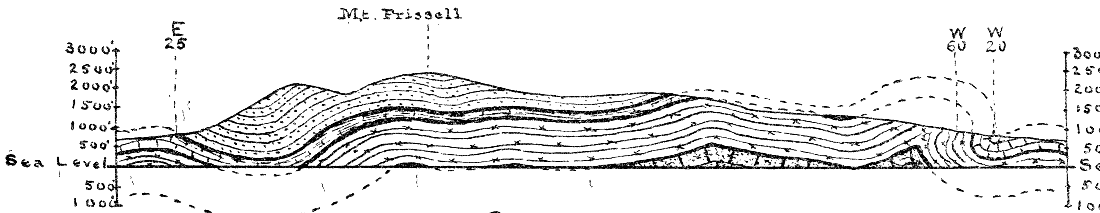
Sea Level
Section F
Mt. Frissell


Sections
through
Mt. Washington, Mass.
Topography based on U.S.G.S. maps and the author's notes.
Horizontal Scale same as Map.
Sections look North.
Canaan Limestone.
Riga Schist.
Egremont Limestone
Everett Schist.
Mt. Fray
Section A
Mt. Sterling
Jug End
Section B
Mt. Cedar
Section C
Mt. Bashbish
Mt. Everett
Section D
Mt. Alandar
Section E
Section F
Mt. Frissell
3000'
2500'
2000'
1500'
1000'
500'
Sea Level
500'
1000'

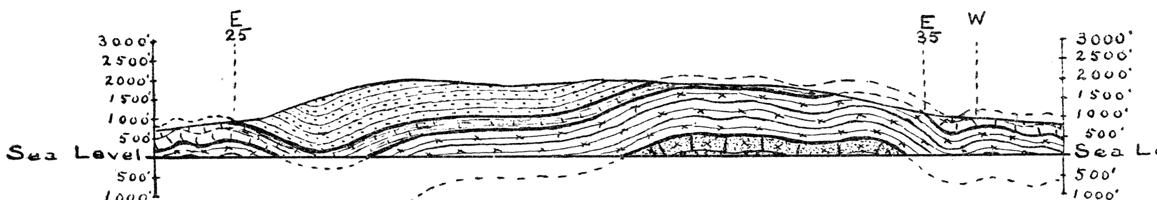
Section E



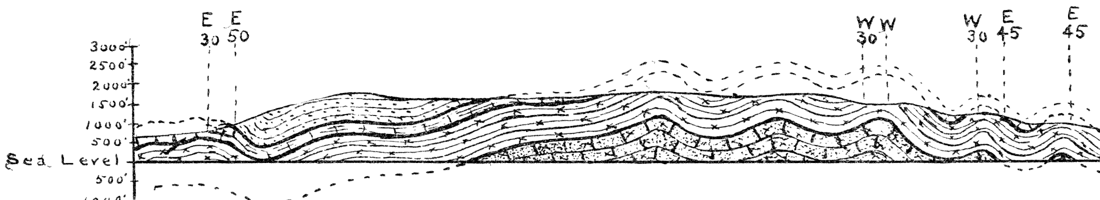
Section F



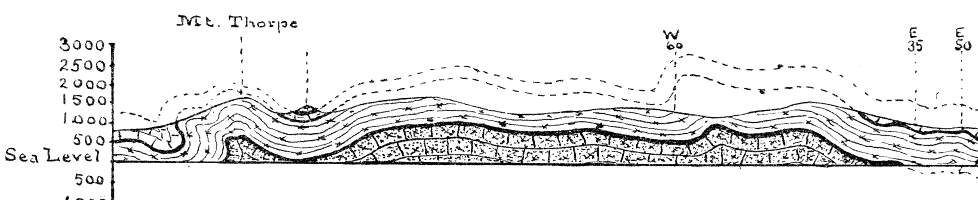
Section G



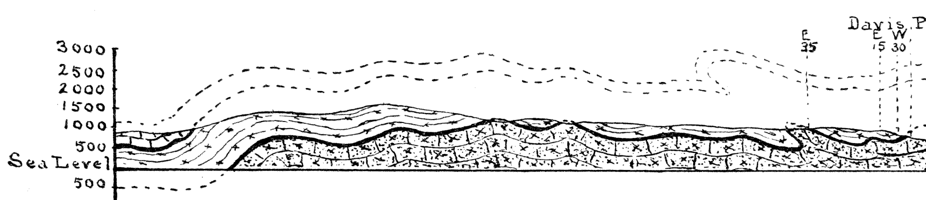
Section H



Section I

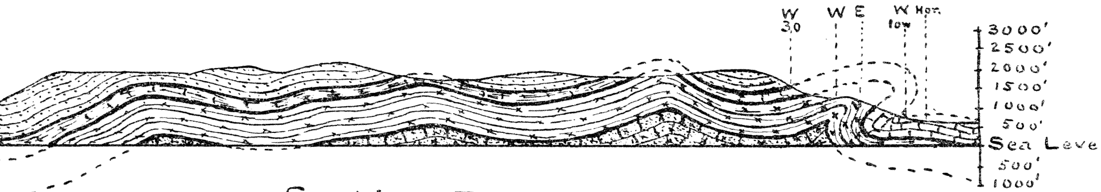


Section J



Section K

Section E



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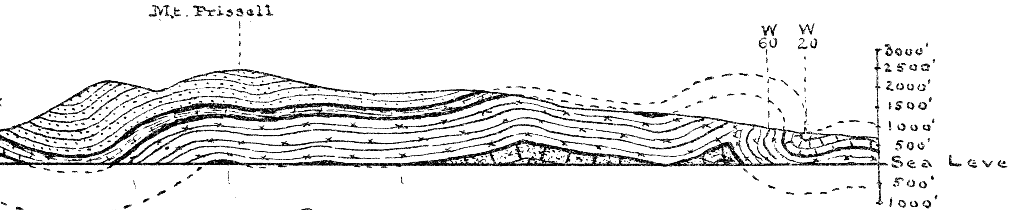

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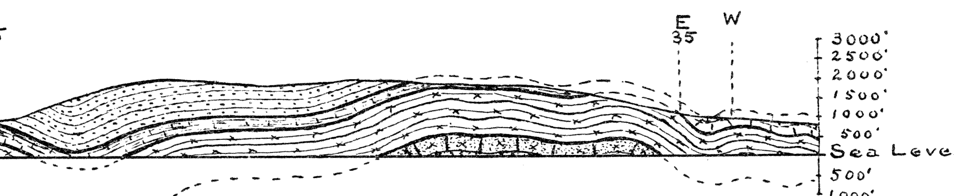

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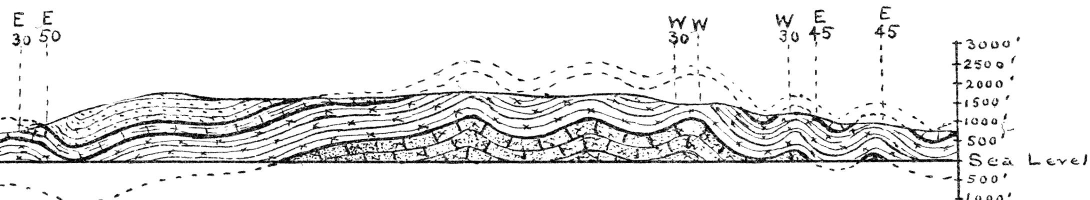
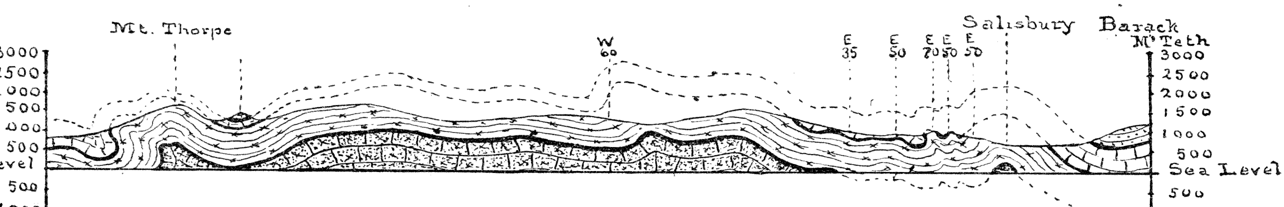


Section I



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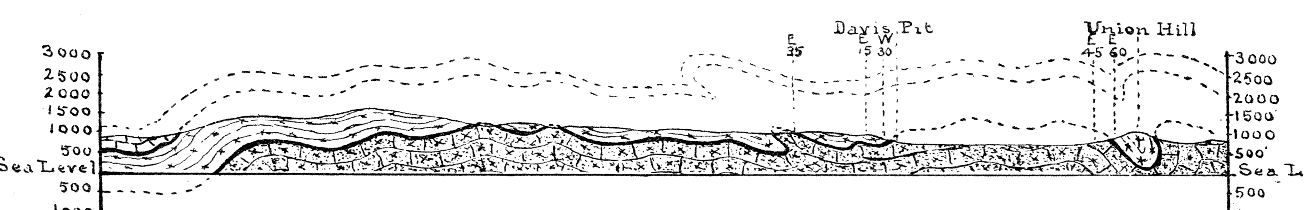

Section K

mountain mass. Proceeding northward, one of the minor synclinals in the western limb of the anticlinorium increases in depth and width by a northerly pitch of its trough line, so as to show at the surface, first, the Egremont Limestone, and then more and more of the Everett Schist. The eastern limb of the anticlinal has, in consequence, been narrowed, then compressed and overturned, until east of Mt. Race its axis[1] inclines westward about 35 degrees. The northerly pitch of its crest line carries it continually deeper, until finally it disappears beneath the limestone on the east flank of Mt. Race (cf. Fig. 1). By this process the anticlinorium of the southern portion has been developed in the central portion into a compound fold consisting of two deeply corrugated synclinals (eastern and western schist ridges) and a central corrugated anticilina, which brings the limestone to the surface in the central plain. Proceeding northward still, the flexures sharpen and deepen and become reversed, much as Professor Dana has described. This narrowing of the folds contracts the mountain at its north end, and the succeeding southerly pitching crest and trough lines bring the limestone higher and higher until the overlying schist disappears altogether. To facilitate the comparison of the flexures, Fig. 4 is introduced, the curves being those of the contact of the Egremont Limestone and the Everett Schist as developed in the series of sections. The map, as well as the sections, show that the small schist ridges in the limestone near Salisbury are mainly infolded Riga Schist with the axes of the folds inclined eastward.

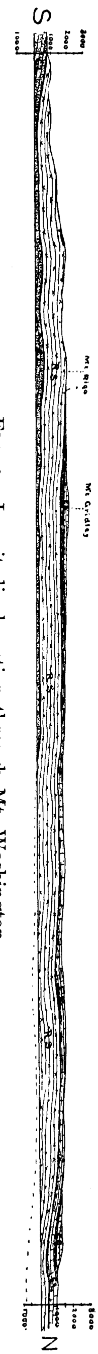

Fig. 3. Longitudinal section through Mt. Washington.

Variable Thickness of the Egremont Limestone.—The upper limestone of Mt. Washington forms the

[1] In this paper the term "axis" is used for the axial-plane bisecting a flexure, and never for the crest line or trough line. Cf. MARGERIE ET HEIM, Les dislocations de l' écorce terrestre. Zürich, 1888, p. 53.

western part of the great belt which Professor Dana has mapped in this section of Berkshire county. While it has not been found possible to accurately measure its thickness, it may be safely stated that the thickness never exceeds 600 to 800 feet, and that the beds thin out toward the south end of the mountain. They

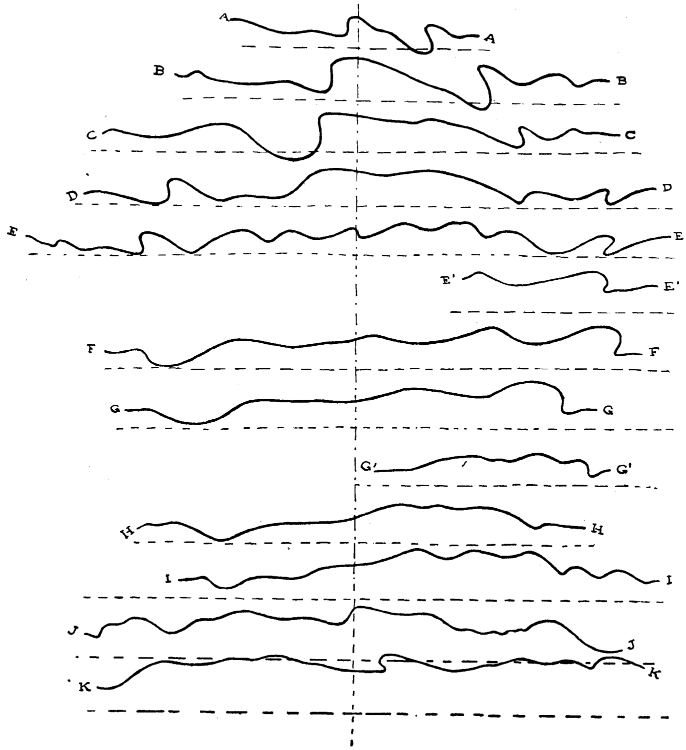

FIG. 4. Series of curves showing the probable form of the flexures in the rocks of Mt. Washington.

also thin out toward the center of the mass from either side. The minimum thickness in the southern portion of the area is probably something less than 100 feet. The general truth of this statement is borne out by an examination of the map and sections (Sage's Ravine, Bear Rock Falls, etc.) As the limestones do not again appear on the southeast flank of the Cornwall-Sharon core of older rocks, it is probable this horizon never

extended much beyond its present limit in a southerly direction. As the bed thins out it becomes more graphitic, indicating also that the conditions attending its formation had here some peculiar local characters.

Metamorphic Character of the Rocks as Indicated by Microscopic Studies.—The microscopic examination of thin sections of rocks from Mt. Washington shows clearly that they are strongly metamorphosed clastics. Evidence has been deduced from the secondary growths of feldspars, garnets, and tourmalines, as well as from the relations of the different metamorphic minerals to one another, to show that the orographic forces to which these minerals owe their development, operated in several more or less distinct periods.[1]

Summary and Conclusions.—What has been set forth in the preceding pages agrees well with Professor Dana's views so far as the northern portion of the area is concerned. In the southern and central portions, however, where the areal and structural relations are more obscure, I have arrived at very different conclusions. This has been due, not to the discovery of errors in Professor Dana's observations, which have been in the main confirmed, but to the collection of a larger number of observations and to the application of some structural principles which were not made use of in his study. A glance at the map will show how perfectly the belt of Egremont Limestone which crosses the southern portion of the mountain, is concealed where it meets the valleys. This belt, the discovery of which furnished a key to the structure, is not at first apparent to the geologist, because at its ends the boundaries of the Riga Schist coincide closely in direction with and form an extension of the boundaries of the Everett Schist.

To summarize briefly the results which have been discussed in the foregoing, the Mt. Washington series consists of four members, which in order of age are as follows: 1) Canaan Dolomite, 2) Riga Schist, 3) Egremont Limestone, and, 4)

[1] Phases in the Metamorphism of the Schists of Southern Berkshire: WM. H. HOBBS. Bull. Geol. Soc. Am., vol. iv., pp. 167–178, pl. 3.

Everett Schist. A somewhat striking lithological distinction, which has been valuable for purposes of identification, is found to separate the two schist horizons, the Everett Schist being entirely free from garnet and staurolite, while the Riga Schist usually (though not always) contains macroscopic crystals of one or both of them. The older rocks are found in the southern portion of the area, a general northerly pitch carrying them successively below the surface as we proceed northward, until at the north end of the mountain we find the upper two members of the series only.

The structure of the mass may be summarized by stating that the beds have been thrown into corrugated folds which seem to have moderate, tolerably symmetrical corrugations at the south end of the mountain, but these corrugations deepen and become frequently overturned as we proceed northward. In the eastern portion of the area the axes of the reversed folds is generally westward. At the extreme south, the structure is a geo-anticlinal, but this develops in the central and northern parts of the area into a geo-synclinal owing to the continued disproportionate deepening and widening of one of its minor western corrugations. The general pitch of the beds is north. A less important southerly pitch which characterizes the northern portion of the area, in combination with the general synclinal structure in cross sections, gives to all the mountain except its extreme southern portion a basin-like character. The rocks are throughout strongly metamorphosed clastics, the orographic disturbances to which they owe their marked crystalline character and porphyritic crystals having operated in several distinct periods. The Egremont Limestone shows a marked diminution in thickness as we proceed southward in the area until it almost disappears. Throughout the mountain plain it is greatly modified, being either a micaceous limestone or calcareous mica schist, or a graphitic schist. The graphitic rock is most developed near the schist contacts and in the southern portion is the only representative of the limestone.

WM. H. HOBBS.

UNIVERSITY OF WISCONSIN, MADISON, WIS.